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Implementation Challenges of Building Information Modelling (BIM) in Small to Medium-Sized Enterprises (SMEs) Participating in Public Projects in Qatar

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ABSTRACT

This research investigates the implementation challenges of Building Information Modelling (BIM) in Small to Medium-Sized Enterprises (SMEs) participating in public projects, with a focus on the construction industry in Qatar. Through a combination of literature review, surveys, and interviews, the study identifies key obstacles such as interoperability issues, financial constraints, organisational and cultural resistance, and the lack of comprehensive training programs.
The literature highlights the fragmented nature of construction projects and the potential of BIM to improve efficiency through enhanced data handling and collaboration. However, SMEs often struggle with the high initial costs of software and hardware, as well as the need for extensive training to bridge the skill gap. Interviews with industry professionals reveal that while mandatory BIM integration in public projects drives adoption, it also exacerbates these challenges for SMEs, which may lack the necessary resources and expertise.
Survey findings indicate that contractors frequently encounter issues with understanding and implementing BIM and meeting the government body standards, suggesting a need for better training and support. The study also emphasises the importance of strategic incremental adoption, where SMEs gradually integrate BIM into their processes, starting with low-level implementation in privately funded projects.
The research concludes that while BIM offers significant benefits for the construction industry, its successful adoption requires targeted support for SMEs. This includes financial incentives, improved interoperability standards, comprehensive training programs, and strategic change management approaches. Addressing these challenges will enable SMEs to fully leverage BIM's potential, enhancing project efficiency and competitiveness in the construction sector.

1. Introduction

The construction industry is undergoing a significant transformation with the advent of BIM, a process that promises to revolutionize project delivery through enhanced collaboration, efficiency,

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and data integration. Despite its potential, the diverse interpretations of BIM among industry professionals highlight its multifaceted nature. BIM can be viewed as a digital representation of a building's physical and functional characteristics, a collaborative process utilising digital tools, a comprehensive integration of project information, or simply as specific software technology [1].

BIM extends beyond traditional 3D models by incorporating various dimensions that enhance its functionality: 4D for time and scheduling, 5D for cost estimation, 6D for sustainability, and 7D for facility management [2]. This technological advancement promises to address the fragmented nature of construction projects, which often use a variety of software leading to potential data loss during information exchange [3].

Moreover, future trends are indicating a major shift, with 40-45 percent of industry value moving towards modern and sustainable practices like off-site construction (OSC), automation, and software development [4]. BIM is particularly advantageous for OSC due to its support for automation [5], underscoring its significance for SMEs to stay competitive in the evolving market and marking an important shift in the industry.

BIM's potential to improve project outcomes is particularly crucial for public projects, where the public sector often lags behind the private sector in adopting new technologies [6]. However, the integration of BIM within SMEs presents considerable challenges. SMEs, which constitute a significant portion of the construction sector, face unique barriers to BIM adoption. These barriers include limited financial resources, lack of technical expertise, resistance to change, and inadequate training programs [7]. The high initial costs of software, hardware, and the need for extensive training exacerbate these challenges [8].

Qatar, a nation undergoing rapid development and playing a key role in the global construction landscape, provides a specific focus for this research. The country's alignment with the Qatar National Vision 2030, which emphasizes sustainable development and modern infrastructure, makes it an ideal case study. Qatar has embarked on ambitious infrastructure projects exceeding $220 billion in value, including major initiatives like Lusail City, the new Hamad International Airport, and preparations for the 2022 FIFA World Cup. To ensure the successful delivery of these complex projects, the Qatari government has recently mandated the integration of BIM in all public project tender documents. This move, led by the Public Works Authority (Ashghal) through the development of the Ashghal BIM Standards (ABIMS), reflects Qatar's commitment to modernizing its construction industry and aligning with international standards such as ISO 19650 [9].

This proactive approach to BIM adoption, particularly Qatar's recent mandate, provides a unique and valuable context for exploring the challenges faced by SMEs in the construction sector. These challenges include navigating regulatory pressures, managing the high expectations for efficiency and innovation in public projects, and addressing the inherent complexities of BIM implementation in a rapidly evolving market. By focusing on Qatar, this study aims to highlight how mandatory BIM adoption influences project outcomes, enhances collaboration, and supports SMEs in leveraging BIM's full potential.

Ultimately, this research investigates the implementation challenges of BIM in SMEs involved in public projects within the Qatari construction industry. By combining a literature review with surveys and interviews, this study aims to identify key obstacles such as interoperability issues, financial constraints, organisational and cultural resistance, and the lack of comprehensive training programs. The findings will provide actionable recommendations to facilitate smoother BIM integration for SMEs, enhancing their competitiveness and project efficiency in the construction sector. Addressing these challenges through strategic incremental adoption, financial incentives, improved interoperability standards, and comprehensive training programs is crucial for enabling SMEs to fully leverage BIM's potential.

1.1. General BIM Implementation Issues

This section addresses several key challenges in BIM implementation that affect its successful adoption across the construction industry. First, interoperability remains a critical concern, as the ability of different BIM tools to exchange data seamlessly is often compromised. Next, organisational and cultural adaptation plays a significant role, where resistance to change and entrenched practices can slow down BIM integration. Additionally, the need for training and skills development is vital, given the varying levels of digital proficiency within the workforce. The financial and legal implications of BIM also pose challenges, particularly regarding investment costs and contract management. Lastly, the lack of standardisation across regions and technical fields creates inconsistencies that hinder the effective use of BIM.

1.1.1 Interoperability

This section aims to explore the current state of data sharing and interoperability among BIM tools and identify their effects on BIM implementation. Using open standards like IFC (Industry Foundation Classes) is essential for improving the compatibility of different BIM tools, enhancing collaboration, data sharing, and project coordination in the construction industry [10]. The significance of data sharing can be highlighted by examining how two architectural drafting software programs interact with a structural engineering software program. The analysis focuses not on the functionalities these tools offer, but on their interoperability and how data is received by the recipient software. Sampaio *et al.,* [11] outline the challenges and limitations encountered when exchanging structural models between BIM systems such as ArchiCAD, Revit, and ETABS using IFC-based models.

The following is a summary of the process and result of each exchange:

- ArchiCAD → IFC → ETABS: The study points out multiple occurrences of data loss and inaccuracies during these transfers. Specifically, it observes that when structural models are transferred from ArchiCAD to ETABS using the IFC format, the result is disconnected elements and inconsistencies, necessitating time-consuming checks and adjustments.
- Revit → IFC → ETABS: The transfer of data from Revit to ETABS using the IFC standard resulted in significant data loss, including issues with recognizing dimensions and material properties, which led to inaccuracies.

Finally, Lai and Deng [12] conclude two key factors contributing to interoperability issues with IFC files: differences in domain knowledge and diverse representation methods. The first issue arises when software tools lack the specific domain knowledge required to accurately interpret objects from other disciplines. The second issue involves the varied methods that different software tools use to represent geometries, properties, and relations, which can lead to inconsistencies, data loss, misinterpretation, or incorrect geometric representations when importing models between tools.

1.1.2 Organisational and cultural adaptation

Organisational culture is defined by the collective values and beliefs that influence a company's behaviour with stakeholders, promoting creativity and adaptability essential for reaching shared objectives [13]. If a culture is entrenched in dominant logic—a set of understandings and beliefs that guide decision-making based on an existing business model, as is often the case in the construction industry [14]—then implementing BIM will be challenging. These challenges are not technical but deeply rooted in organisational culture and behaviour [15].

Currently, there is resistance from various stakeholders involved in the implementation process due to the perceived threat to existing work practices and roles [16] and due to established processes and traditional ways of working [17]. The shift to a fully implemented BIM workflow can also lead to disputes related to new responsibilities and the redefinition of roles. Organisations might lack mature mechanisms to resolve such disputes, which can disrupt the implementation process [18].

However, culture can adapt to changing opportunities and pressures [19], allowing organizations to evolve. For instance, some contractors have restructured to facilitate BIM implementation by creating dedicated BIM departments and hiring experts [20]. Yet, such solutions can be costly, especially for SMEs with limited resources [21]. To fully realize BIM's potential and justify its investment, the industry needs a better understanding of its benefits, including integration with functions like energy simulation, estimating, and facilities management [21].

1.1.3 Training and skills development

Shojaei *et al.,* [22] identifies a significant challenge in the UK construction industry as the variability in BIM training and skill development, highlighting disparities in digital literacy and essential software skills among the workforce. The study points to a general lack of understanding of BIM's comprehensive benefits and the presence of project teams with varying levels of BIM knowledge, which complicates implementation. This necessitates targeted training programs to ensure effective collaboration and use of BIM tools [23]. Additionally, the financial burden of training, coupled with concerns about cost versus immediate benefits, poses a challenge for organisations [24]. Wu and Issa [25] further note that these issues are exacerbated by an aging workforce, the profession's low appeal to youth, and evolving skill-set demands due to technological advancements like BIM.

1.1.4 Procurement and legal implications

Vass and Gustavsson [8] add to these challenges by highlighting the need to alter procurement strategies and contracts to demand BIM-based work practices. This complexity makes it difficult for project managers and suppliers to adhere to new requirements, resulting in additional time and effort to manage supplier compliance, often necessitating additional contracts. Migilinskas *et al.,* [17] note that high-level collaboration across various stakeholders would be difficult to achieve under traditional contract arrangements, and the lack of collaborative contractual models can limit the full benefits of BIM.

Eadie *et al.,* [26] highlight that implementing BIM can lead to various legal issues. The primary concern is determining who owns the BIM model, as multiple stakeholders collaborate on its creation. This collaboration makes it difficult to assign accountability for errors. In addition to ownership issues, there are risks related to design liability and the integrity of BIM models. Without clear contractual provisions, it is challenging to determine who is responsible for ensuring the accuracy and completeness of the models. This lack of clarity can lead to legal uncertainties and potential disputes among the stakeholders involved [27].

Taghizadeh *et al.,* [28] add that the lack of established protocols for responsibility further complicates legal accountability and emphasise the need for comprehensive BIM execution plans (BEPs) that explicitly define each party's responsibilities and incorporate solutions such as professional indemnity insurance and tighter contract terms. Addressing these legal uncertainties is crucial for achieving the full benefits of BIM while mitigating risks and ensuring that liability is fairly distributed among project participants.

1.1.5 Standardization

The adoption rates of BIM ISO 19650 standards vary across different countries and regions, influenced by factors such as national policies, market dynamics, and local industry standards. Kassem and Succar [29] note that BIM diffusion rates are uneven and influenced by these factors. For instance, while some countries have well-distributed BIM adoption across various areas, others have unbalanced distributions, leading to different adoption challenges. Additionally, countries adopt different policy actions and implementation approaches, further affecting the rate and manner of BIM adoption.

This inconsistency affects BIM adoption, as the absence of unified standards and clear policy directives can hinder its effective use. Furthermore, there is an observed absence of standardized contracts that specifically address the requirements and responsibilities related to BIM implementation. This can lead to legal and procedural ambiguities, making it difficult for parties to agree on terms and collaborate effectively [18]. Therefore, governments in nations where BIM is still emerging are encouraged to adopt such measures for enhanced implementation [30].

On the technical front, some technical standards are not clearly defined and are not fully supported by current BIM software available, creating a gap in standardization and application. Lan *et al.,* [31] highlight a critical challenge due to the lack of unified BIM technology standards specifically tailored for tunnel engineering. They emphasize the need for comprehensive standards to facilitate information sharing, exchange, and management across the lifecycle of tunnel projects.

Another study by Muller *et al.,* [32] reveals IFC interoperability challenges for cast-in-place concrete structures in BIM due to their monolithic nature and reinforcement detailing. Despite some progress, issues with material data and structural overlaps remain.

Additionally, Alreshidi *et al.,* [33] note consistent problems with clash detection, where its efficiency and effectiveness are limited by various technical, organisational, and cultural factors. For instance, automated clash detection tools in BIM often generate many irrelevant clashes (false positives), requiring significant time and resources to filter and resolve. MEP (Mechanical, Electrical, and Plumbing) systems are particularly prone to coordination issues due to their complexity, leading to frequent clashes with other design elements. Furthermore, they add that the current structure of Common Data Environments (CDEs) often encourages isolated working by creating separate digital spaces for different disciplines, which hampers early collaboration and effective clash avoidance. They conclude that technological barriers related to standards interoperability and cultural resistance to changing traditional working practices prevent BIM from achieving its full potential in effective clash detection and integrated design solutions.

1.2 SMEs Implementation Issues

Understanding the critical role SMEs play in the construction industry is essential for addressing BIM implementation issues. Nearly a fifth of these enterprises contribute significantly to the sector's workforce and economic output [34]. However, SMEs face unique challenges in adopting BIM, including limited capacity, inadequate Information and Communication Technology (ICT) infrastructure, and insufficient resources for training and implementation. Recognizing these challenges is crucial for bridging the gap between policy aspirations and the realities of BIM implementation [35]. By doing so, reform policies can be designed to avoid disproportionately disadvantaging smaller firms and instead support a more inclusive and effective adoption of digital technologies across the industry.

This section will explore the primary challenges SMEs face in BIM implementation, as commonly identified in the literature, along with suggested techniques for successful adoption.

1.2.1 Feasibility

The construction industry is predominantly made up of SMEs, characterized by low barriers to entry and a fragmented market, fitting the model of "perfect competition" [36], as illustrated in Table 1.

Table 1
Construction Markets

	Perfect Competition	Monopolistic competition	Oligopoly
Subcontractors	Labour based subcontracting	Mechanical services (HVAC)	Lifts, building automation
Contractors	Many small and medium contractors	Some medium sized contractors	Large main contractors

Therefore, investing in BIM implementation is becoming increasingly more prominent due to rising governmental mandates and the competitive nature of the market, as BIM is regarded as an innovative and sustainable solution that improves project efficiency [37].

Kassem *et al.,* [38] identify several substantial initial investment costs associated with BIM implementation, including the cost of software and necessary hardware upgrades to support advanced BIM tools. These costs can be particularly challenging for SMEs, which often need to upgrade their systems and hire new employees with specific expertise in BIM, adding to both the initial and ongoing financial burden. Vidalakis *et al.,* [39] further emphasize that the financial capacity of SMEs is a critical barrier to BIM adoption, as the ongoing expenses associated with BIM can outweigh the perceived benefits, making it difficult for smaller firms to allocate resources without assurances of a realistic return on investment (ROI). This underscores the need for targeted support and initiatives to alleviate these costs and encourage wider adoption within the SME sector.

Furthermore, Dainty *et al.,* [7] note that policies promoting BIM adoption have not adequately addressed the financial and structural constraints of SMEs, leading to a growing digital divide between larger firms that can afford these investments and smaller firms that cannot. This results in a two-tier market where the benefits of BIM are mostly claimed by larger firms. The study adds that the investment in BIM is unlikely to be justified without guaranteed efficiencies and productivity gains across their entire market portfolios. This uncertainty in predictable outcomes from BIM implementation further discourages SMEs from adopting the technology.

Hosseini *et al.,* [40] has studied the initial costs SMEs must incur for BIM implementation in the Australian market. These costs are primarily categorized into technology-related expenses, process/people-related expenses, and economic-related expenses. Below is a table summarizing the deduced main initial costs that SMEs must incur for BIM implementation.

Table 2
SME's Potential Incurred Initial Costs

Cost Category	Description
Software Costs	Significant upfront costs include purchasing or subscribing to BIM software, involving initial licensing fees and ongoing subscription costs (e.g., Autodesk Revit, ArchiCAD).
Hardware Upgrades	Investment in high-performance computing hardware, including new workstations, servers, powerful processors, ample RAM, and high-quality graphics cards to support BIM software.
Training and Development	Costs associated with training staff for effective BIM implementation, covering training programs and the time employees spend away from their regular tasks.
Consultancy Fees	Fees for BIM consultants to assist with initial setup, integration, and providing expertise and guidance on best practices.
Process Re-engineering	Costs related to re-engineering existing workflows and processes to integrate BIM effectively, including process analysis and change management.
Data Migration	Costs for migrating existing project data into the BIM environment, including digitizing physical documents and converting digital files to compatible formats.
Maintenance and Support	Ongoing costs for maintaining and supporting the BIM system, including software updates, technical support, and potentially hiring/training IT staff.
Additional Costs	Costs such as network upgrades, purchasing cloud storage solutions, and implementing cybersecurity measures to protect BIM data.

These initial costs can be significant, and the financial burden is often a major barrier for SMEs considering BIM adoption. However, the long-term benefits of improved productivity, better project visualization, and enhanced collaboration often justify the initial investment.

1.2.2 Standards and policies

SMEs face significant challenges in adopting ISO 19650 standards due to difficulties in interpreting the complex terminologies and requirements, which hinder effective implementation. They often lack the necessary technological infrastructure and expertise due to uneven levels of digital maturity and financial constraints, limiting their ability to invest in required technology and training. Additionally, SMEs struggle with creating bespoke information workflows tailored to ISO 19650, adding complexity to their operations, and hindering standardization efforts [41].

Furthermore, A study by Yang *et al.,* [42] highlights that reform policies in China do not effectively support SMEs in adopting BIM. The study found significant regional variations in BIM adoption, with regions having larger construction industry scales being more likely to implement BIM policies. This is because larger construction projects derive substantial benefits from BIM, making the investment worthwhile. In contrast, smaller projects are often not seen as justifying the investment in BIM. Despite the adoption of BIM policies, several challenges hinder effective implementation. These include a lack of technical expertise, insufficient financial support, and resistance to change within the industry. The study emphasises the need for a more balanced and supportive policy framework to overcome these barriers and further enhance BIM adoption.

1.2.3 Case study - SMEs during the UK 2016 mandate

The UK government mandated fully collaborative 3D BIM (Level 2) for centrally procured construction projects by 2016 [43]. BIM Level 2 involves collaboration where stakeholders use their own 3D CAD models and share design data using a common file format like IFC, enabling information exchange and coordination through a Common Data Environment (CDE) [44]. To align with the need for a unified approach to information management, particularly as project teams increasingly consist of organizations from different countries, the UK has adopted the international standards known as ISO 19650.

Despite these advancements, SMEs face barriers such as limited financial capacity and unfamiliarity with BIM software and concepts, which hinder adoption. Effective policy implementation must address these challenges by providing financial assistance and training programs to ensure successful BIM adoption [45].

Awwad *et al.,* [46] add that the mandate primarily signifies that SMEs not meeting this requirement will be unable to bid for public government projects. Despite efforts to implement BIM gradually, BIM Level 2 adoption is primarily seen in large companies, with SMEs lagging behind. As a result, SMEs are missing out on opportunities in both public and private sector projects. Specifically, the study included that 40% of SMEs miss out on 90% of the public projects they bid for, and over 50% have seen a decrease in their success rate for public construction projects over the past five years. This decline means that SMEs are at risk of losing competitive advantage in the market.

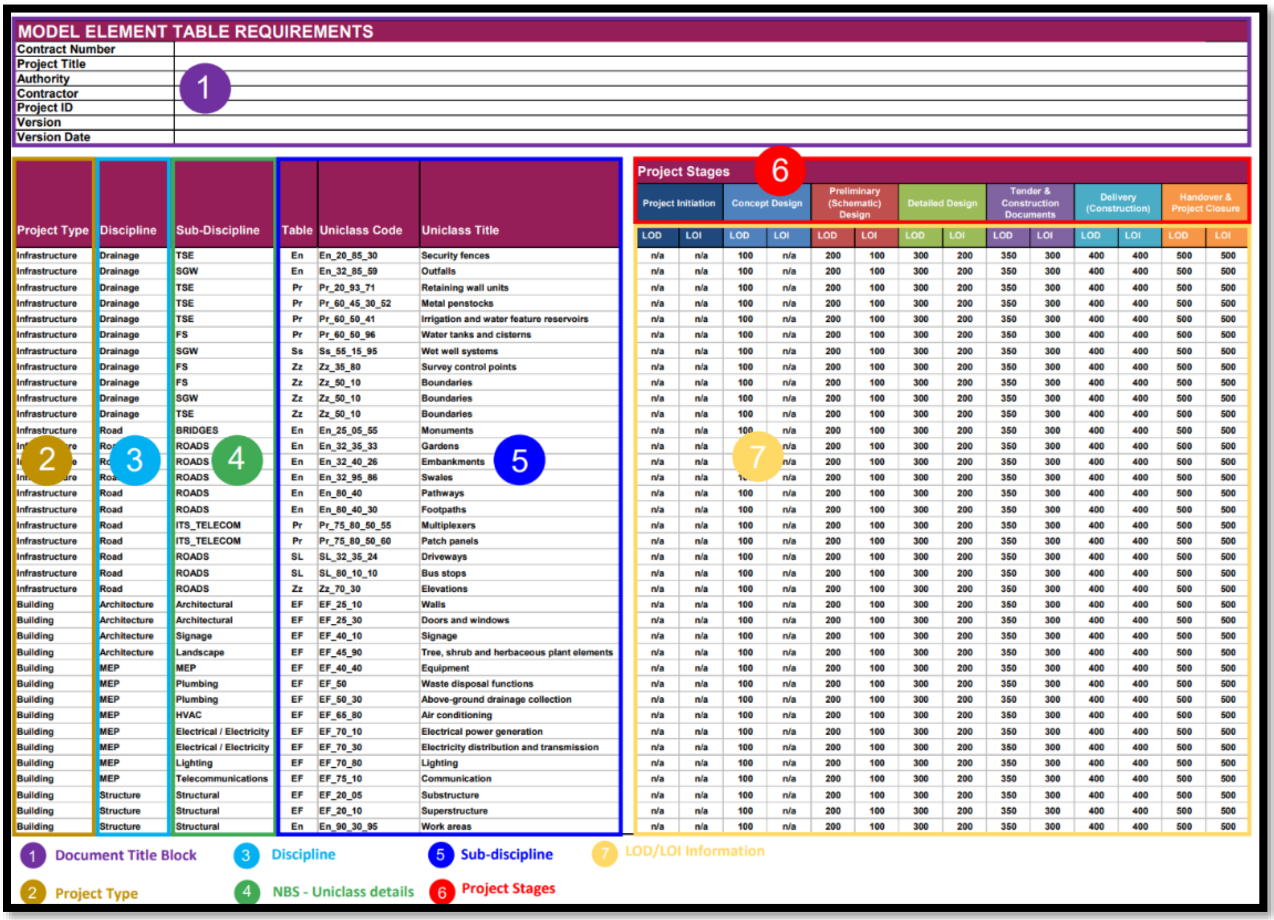
2. Methodology

The research design adopted for this study follows a mixed-methods approach, integrating both qualitative and quantitative data collection techniques to provide a comprehensive understanding of the challenges faced in participating in public projects in Qatar. This approach is particularly suitable for the study as it combines the strengths of both qualitative and quantitative research, allowing for a more nuanced analysis that effectively captures the complexity of the subject matter.

Throughout the data collection and analysis process, the study primarily references the standards set by Qatar’s Public Works Authority. Established in 2004, Ashghal is responsible for the planning, design, procurement, construction, delivery, and asset management of all infrastructure projects and public buildings in Qatar [47]. Drawing a parallel with the UK's 2016 BIM Mandate, Ashghal has similarly incorporated BIM directives into its tendering guidelines for the building sector, making them a requirement for entering the tendering process. Although these directives have not yet been introduced in the roads sector, Ashghal provides comprehensive qualitative and quantitative guidelines for defining the "Level of Information Need" (LoIN) in BIM projects, ensuring that the required level of detail is consistently maintained. The LoIN is divided into two key components:

- Level of Detail (LOD): Defines the graphical representation of model elements.
- Level of Information (LOI): Specifies the non-graphical information associated with model elements.

These components are illustrated in Figure 1, showing their distribution across different disciplines with varying ratings depending on the project stage.



MODEL ELEMENT TABLE REQUIREMENTS

Contract Number	
Project Title	
Authority	
Contractor	
Project ID	
Version	
Version Date	

Project Type	Discipline	Sub-Discipline	Table	Uniclass Code	Uniclass Title	Project Initiation		Concept Design		Preliminary (Schematic) Design		Detailed Design		Tender & Construction Documents		Delivery (Construction)		Handover & Project Closure	
						LOD	LOI	LOD	LOI	LOD	LOI	LOD	LOI	LOD	LOI	LOD	LOI	LOD	LOI
Infrastructure	Drainage	TSE	En	En_20_85_30	Security fences	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	SGW	En	En_32_85_59	Outfalls	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	TSE	Pr	Pr_20_93_71	Retaining wall units	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	TSE	Pr	Pr_60_45_30_52	Metal penstocks	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	TSE	Pr	Pr_60_50_41	Irrigation and water feature reservoirs	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	FS	Pr	Pr_60_50_96	Water tanks and cisterns	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	SGW	Ss	Ss_55_15_95	Wet well systems	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	FS	Zz	Zz_35_80	Survey control points	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	FS	Zz	Zz_50_10	Boundaries	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	SGW	Zz	Zz_50_10	Boundaries	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Drainage	TSE	Zz	Zz_50_10	Boundaries	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	BRIDGES	En	En_25_05_55	Monuments	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
[illegible]	[illegible]	ROADS	En	En_32_35_33	Gardens	n/a	n/a	[illegible]	n/a	200	100	300	200	350	300	400	400	500	500
[illegible]	[illegible]	ROADS	En	En_32_40_26	Embankments	n/a	n/a	[illegible]	n/a	200	100	300	200	350	300	400	400	500	500
[illegible]	[illegible]	ROADS	En	En_32_95_86	Swales	n/a	n/a	[illegible]	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ROADS	En	En_80_40	Pathways	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ROADS	En	En_80_40_30	Footpaths	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ITS_TELECOM	Pr	Pr_75_80_50_55	Multiplexers	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ITS_TELECOM	Pr	Pr_75_80_50_60	Patch panels	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ROADS	SL	SL_32_35_24	Driveways	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ROADS	SL	SL_80_10_10	Bus stops	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Infrastructure	Road	ROADS	Zz	Zz_70_30	Elevations	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Architecture	Architectural	EF	EF_25_10	Walls	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Architecture	Architectural	EF	EF_25_30	Doors and windows	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Architecture	Signage	EF	EF_40_10	Signage	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Architecture	Landscape	EF	EF_45_90	Tree, shrub and herbaceous plant elements	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	MEP	EF	EF_40_40	Equipment	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Plumbing	EF	EF_50	Waste disposal functions	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Plumbing	EF	EF_50_30	Above-ground drainage collection	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	HVAC	EF	EF_65_80	Air conditioning	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Electrical / Electricity	EF	EF_70_10	Electrical power generation	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Electrical / Electricity	EF	EF_70_30	Electricity distribution and transmission	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Lighting	EF	EF_70_80	Lighting	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	MEP	Telecommunications	EF	EF_75_10	Communication	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Structure	Structural	EF	EF_20_05	Substructure	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Structure	Structural	EF	EF_20_10	Superstructure	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500
Building	Structure	Structural	En	En_90_30_95	Work areas	n/a	n/a	100	n/a	200	100	300	200	350	300	400	400	500	500

Fig. 1. Model Element Table Requirements Overview (Source: PWA ASHGHAL Domain Guide)

2.1 Interviews – Qualitative Research

Interviews were conducted with employees holding various positions and titles within the organisation. The following table outlines the job titles, and the corresponding sets of questions posed to each. The questions were tailored to the specific roles; for example, managers were asked more managerial oriented questions, while BIM managers/coordinators/experts received a higher proportion of technical questions of BIM implementation. The interview questions were also tailored with an emphasis on SME adaptivity.

Table 3
Interviewees list

Position Title	Form of Questions	Company	Company type
(1) Head of a Department	Managerial	Ashghal	Client
(2) Senior Project Manager	Managerial	AECOM	Consulting
(3) BIM Manager (Buildings Dep.)	Expert	Ashghal	Client
(4) BIM Coordinator (Roads Dep.)	Expert	Ashghal	Client
(5) Project Director	Managerial	KEO International	Consulting
(6) BIM Coordinator	Expert	KEO International	Consulting

2.2 Surveys – Quantitative Research

In this research, a survey is developed directed at BIM experts, containing questions tailored to their expertise and perceptions into the technical and practical aspects of BIM implementation, as well as their insights on BIM processes integration into SMEs. The surveys were sent out at an invite only basis, targeting relevant stakeholders within consultant and client designer teams and a few contractors involved in public projects in Qatar. This approach ensures a reliable set of collection of data, capturing both managerial and expert viewpoints, which is crucial for a macro-level SME BIM adoption understanding. In addition to that, the survey includes Likert scale questions that measure the intensity of respondents' feelings or attitudes towards the impactfulness of a particular issue.

2.3 Practical Example

This section investigates the viability of BIM's interoperability by investigating data sharing techniques between Revit (Autodesk family) and ArchiCAD (Ghraphisoft) via a practical investigation. The study involves a modelling exercise in Revit, testing data sharing via IFC to ArchiCAD, and comparing the findings with existing literature on interoperability issues between BIM models. The goal is to pinpoint practical efficiency challenges and opportunities offered by these BIM tools. This analysis enhances the understanding of BIM's strengths and limitations. The emphasis is placed on their interoperability rather than their individual functionalities.

The integration of these qualitative and quantitative methods, along with practical examples, provides a solid triangulation of data, ensuring that the research findings are both reliable and valid. By combining these approaches, the study not only captures the statistical significance of the issues but also delves into the underlying reasons behind the challenges faced by SMEs in BIM implementation.

3. Results
3.1 Interview Findings

The interviews conducted with key stakeholders involved in the implementation of BIM in public projects revealed several important insights.

One key takeaway from discussions with a department head at Ashghal (1) was the emphasis on making BIM mandatory in public project tender documents. This requirement ensures that contractors submit detailed BEPs that meet specified Levels of Information (LOI) and Levels of Detail (LOD), as outlined in Table 1. Qatar's adherence to the international BIM standards ISO 19650 supports goals such as waste reduction, process simplification, and long-term automation to align with global industrialization trends.

An important perspective from a BIM manager at Ashghal (3) highlights the critical role of effective communication with contractors in ensuring streamlined efficiency in BIM works and waste reduction. He noted that the biggest problem for small-medium sized contractors is their reliance on traditional methods, which often lead to communication barriers and inefficiencies. He suggests that they should incrementally implement BIM into their business model, starting with privately funded projects that allow for low-level BIM adoption, eventually meeting public project requirements. Despite its potential, he believes that SMEs main challenges are due to limited R&D investment and slow adoption of innovations.

Additionally, a BIM coordinator at KEO International (6) adds that a recurring issue is contractors frequently failing to meet the required LOI and LOD pre- and post-tendering stage. During tendering, there are often discrepancies, with contractors sometimes delaying the submissions and promising to meet the required standards in subsequent stages but failing to do so. He believes this is a result of a mix of traditional techniques with modern BIM methodologies leads to inconsistencies with Ashghal's standards. An example of this is the use of paper-based documentation and project records by the contractor that needs to be digitized and integrated into a central BIM database, which can be a significantly time-consuming task. The interviewee (6) believes contractors might opt to use traditional techniques instead of modern BIM criteria for several reasons. He suggests that many contractors are more accustomed to traditional methods and may lack the training or experience needed for BIM software. He also points out that established processes and workflows based on traditional techniques can be difficult to change without causing significant disruption. Finally, He noted some problems with interoperability issues when it came to receiving data from software with different families, urging the use of IFC to facilitate the exchange. This process is noted to have more errors in data exchange from transferring through a single of family like Autodesk (via DWG across multiple software). This issue can also cause time delays as it would lead to resubmission forms for the contractor as some software forms used do not meet the LOI and LOD standards.

A senior project manager at AECOM (2) complements (6) by labelling the process of contractors hiring third-party consultants/subcontracts to meet Ashghal's BIM mandates as an issue that causes inefficiency due to potential communication delays, lack of deep project familiarity, and misalignment with the company's specific processes and standards. He leaned more towards an in-house BIM team that offers a greater efficiency due to better integration with internal workflows, quicker communication, and deeper project understanding. This leads to faster decision-making, consistency in standards, and immediate problem-solving capabilities. This allows to meet the Ashghal's standards and eliminate transaction costs. Interviewee (2) also proposed an hiring the third-party entity to construct and train a developing in-house team within the contractor entity, rather than perform the works themselves to meet the criteria. Finally, he concluded the interview by noting that, when it comes to SMEs, he believes that simpler projects (based on the assumption that SMEs are more likely to bid on low complexity projects) might not justify the complexity and expense of a full BIM implementation, leading contractors to rely on traditional methods.

Another perspective from Ashghal's BIM manager at the roads department (4) noted significant gaps in the infrastructure, roads, and highways sectors of BIM efficiencies in the industry. Due to these gaps, the use of BIM has not been fully mandated in this sector, and traditional techniques remain prevalent. The manager indicated that the adoption of BIM in infrastructure projects is still awaiting broader acceptance and mainstream integration within the industry.

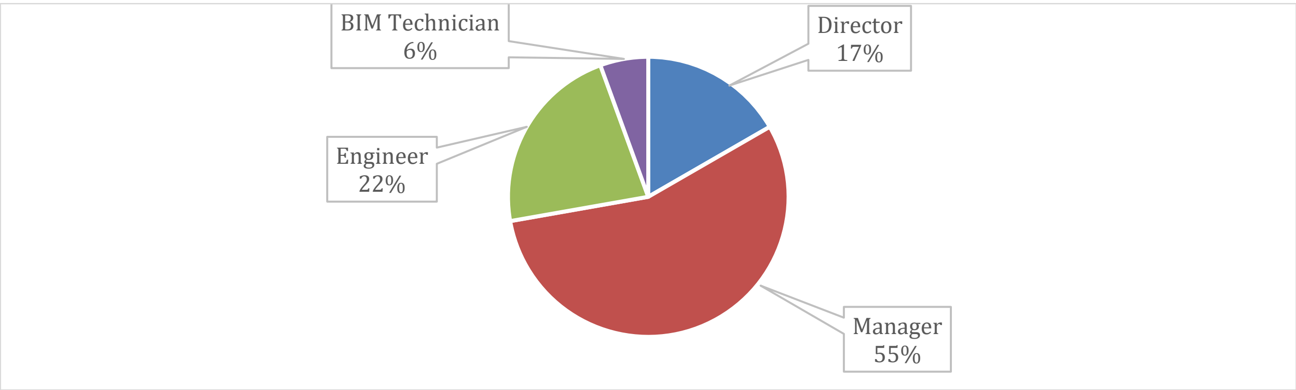
The integration of these interview insights with the broader literature reveals common challenges in BIM implementation among SMEs in Qatar. Resistance to change, substantial initial investments, and a lack of skilled personnel and resources are prevalent issues. The literature verifies the interviewees' suggestions that while BIM can enhance project efficiency and reduce costs in the long run, the transition phase remains challenging for SMEs. To address these challenges, incremental adoption, enhanced training programs to include consultants or a third-party entity to implement and train current staff, and increased R&D investment are recommended.

3.2 Survey Findings

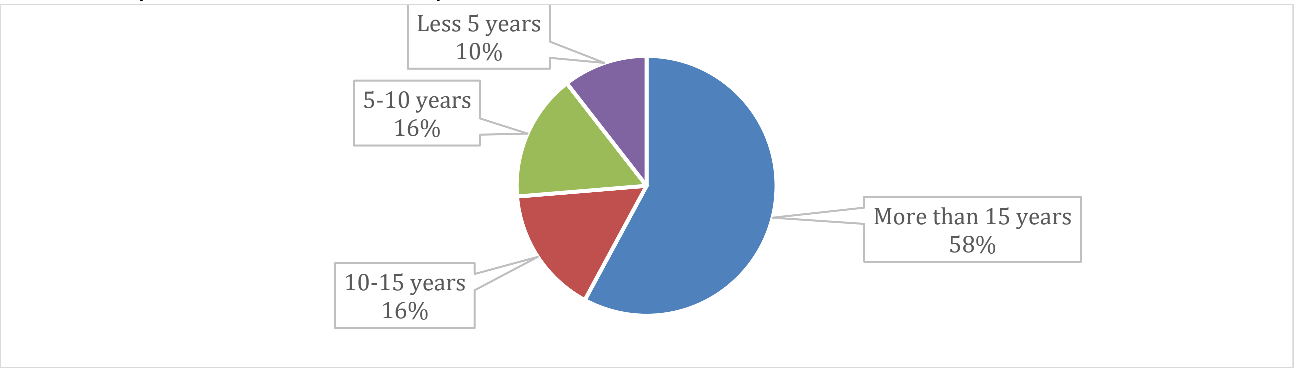
The survey included 19 participants of directly BIM related experts in the field of construction. The questions and results are as follows:

Section 1: General Questions

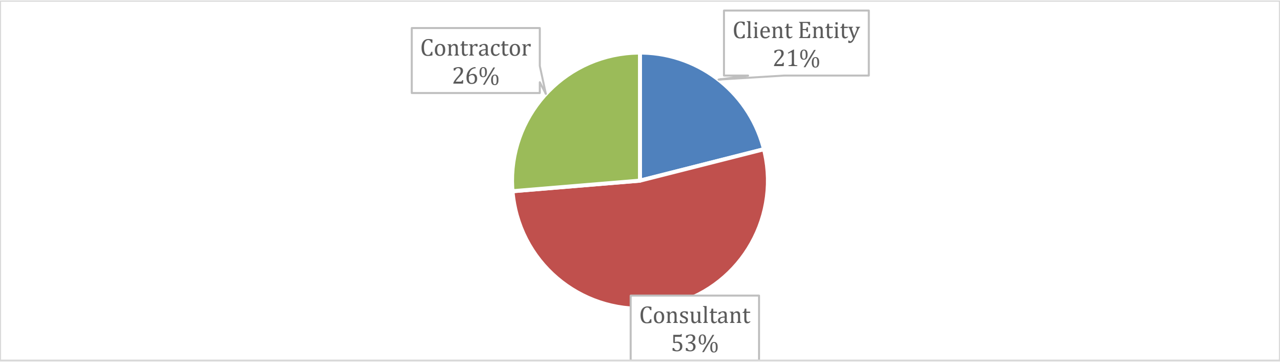
Position title



Years of experience in the industry

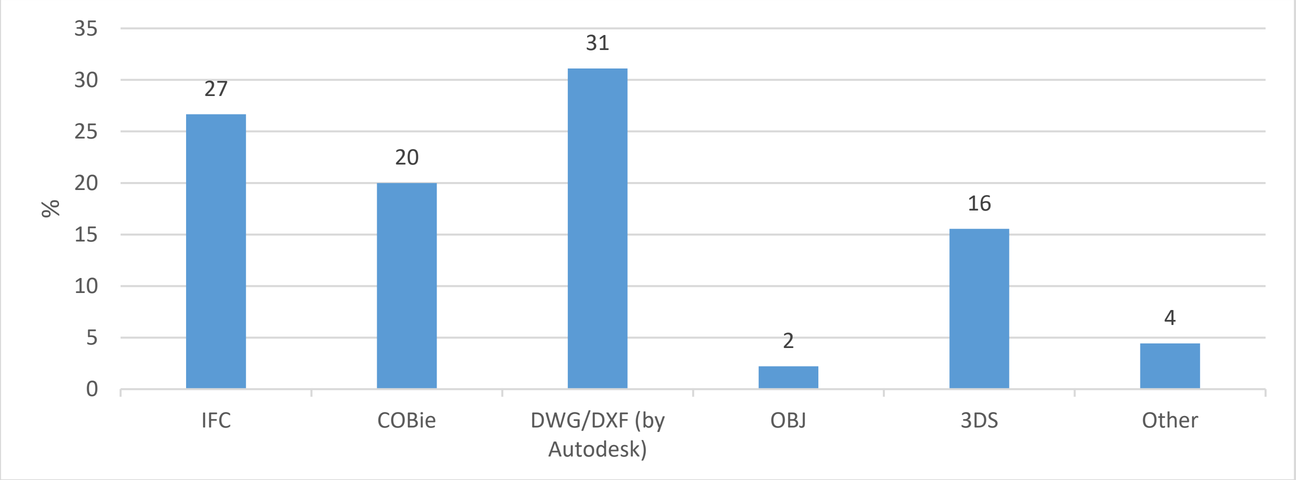


Type of organisation

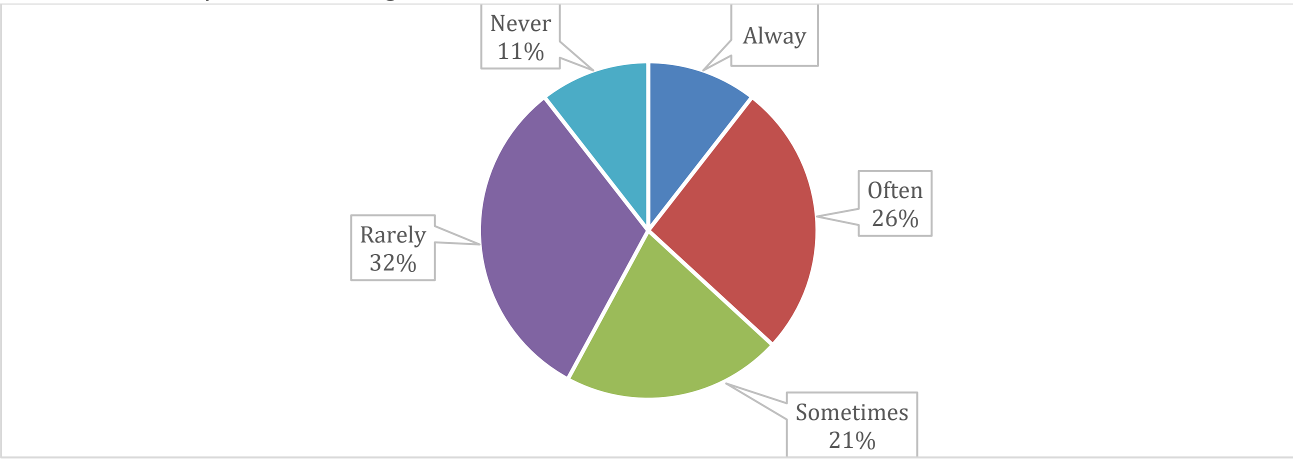


Section 2: Technological and Interoperability Challenges

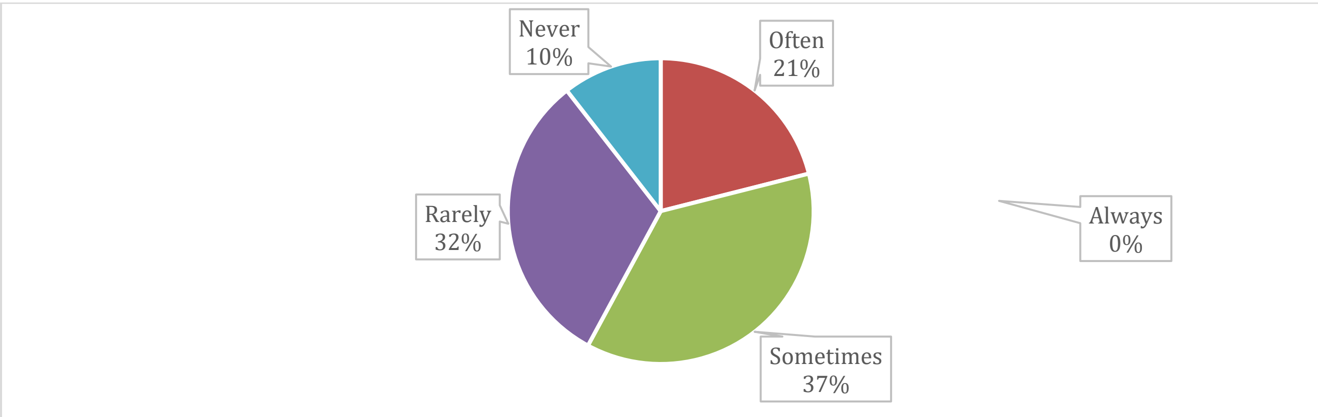
What BIM software interoperability tools do you use?


35
30
25
20
15
10
5
0
%
27
20
31
2
16
4
IFC
COBie
DWG/DXF (by Autodesk)
OBJ
3DS
Other

How often find yourself having to transfer data between two different BIM software?

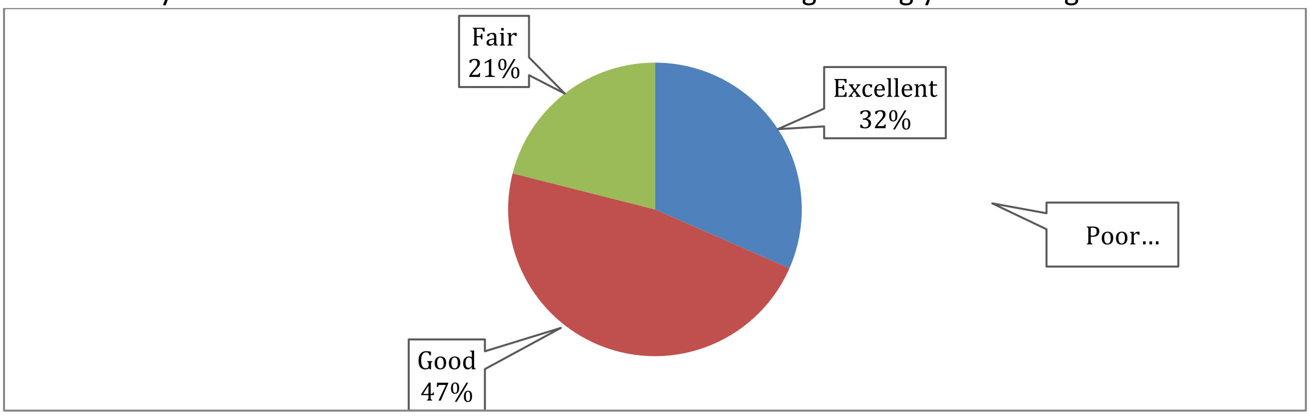


How often do you encounter interoperability issues when transferring data between different BIM software?

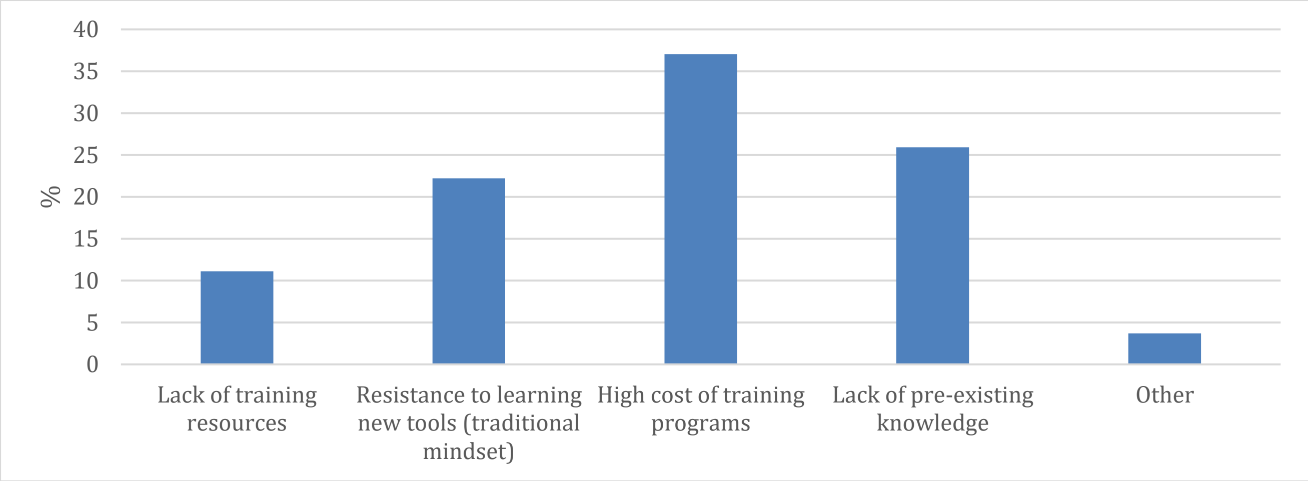


Section 3: Training and skills challenges

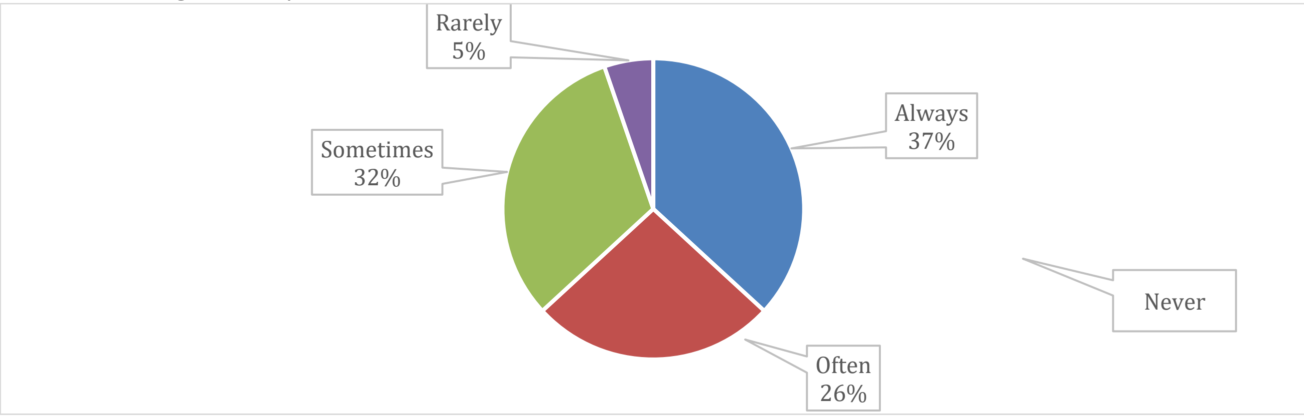
How would you rate the current level of BIM skills and training among your colleagues?



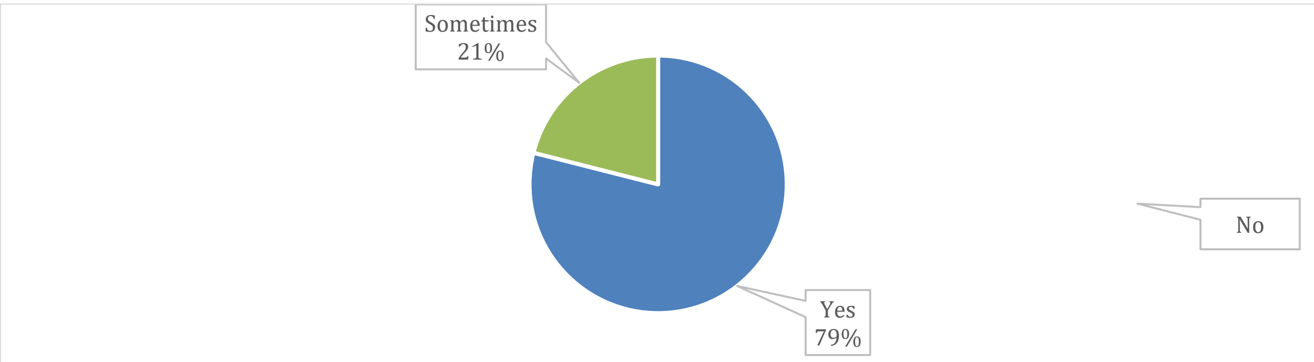
What are the biggest challenges in training staff on BIM tools and processes?



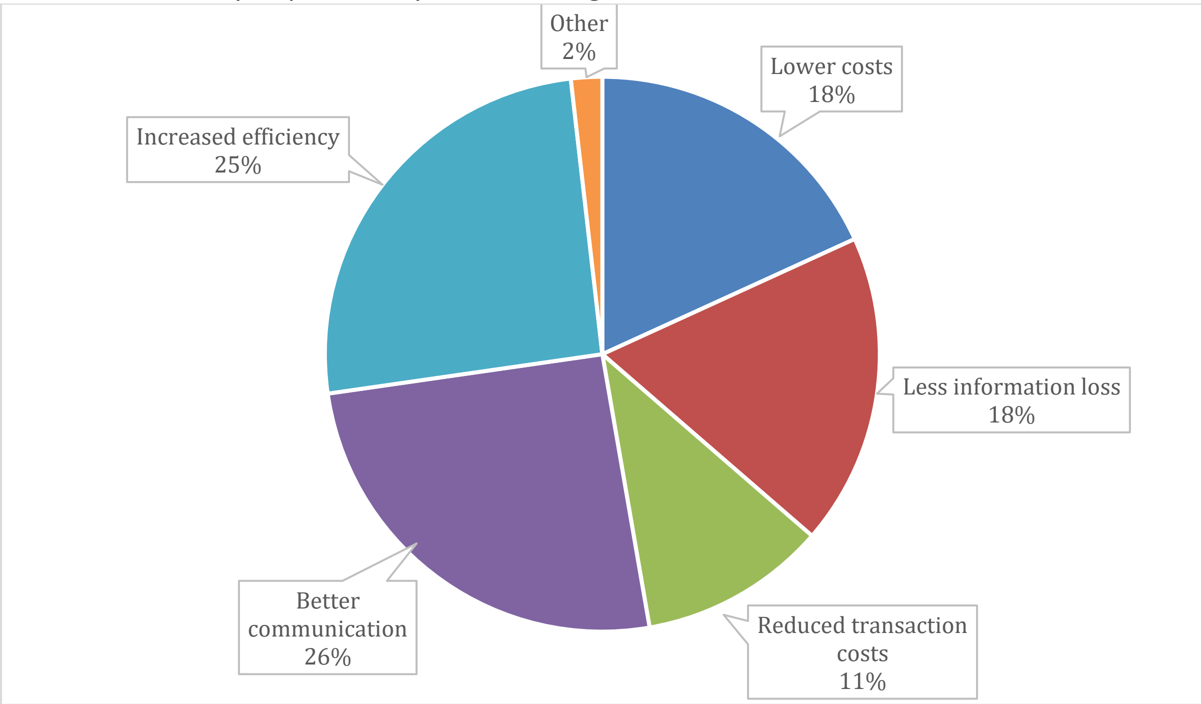
In your experience, how often do you encounter issues with contractors regarding their understanding and implementation of BIM?



Do you think that having an in-house BIM team is more efficient than hiring third-party consultants or subcontractors to handle BIM work?

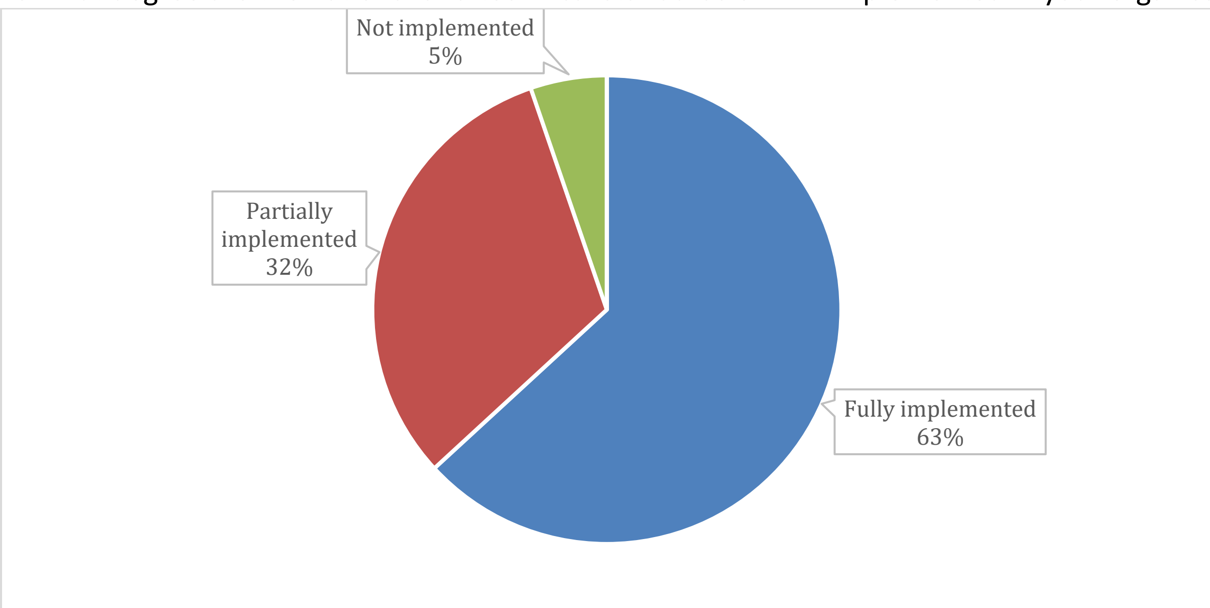


What benefits do you potentially see in having an in-house BIM team?

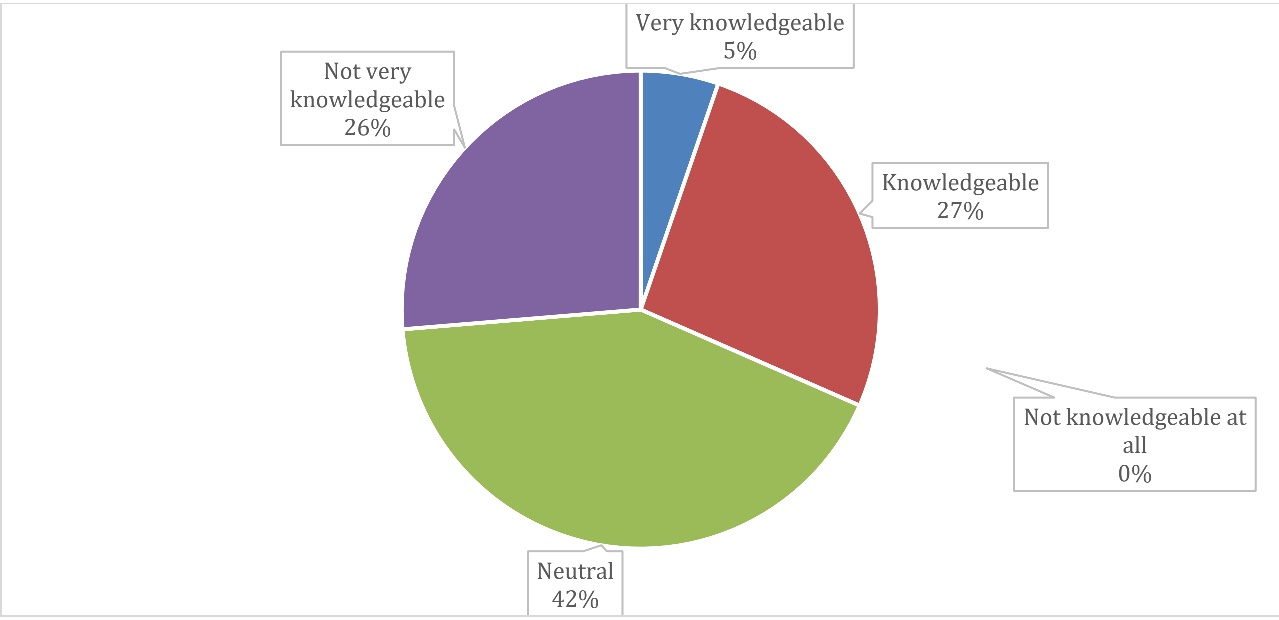


Section 4: Standardization and legal issues

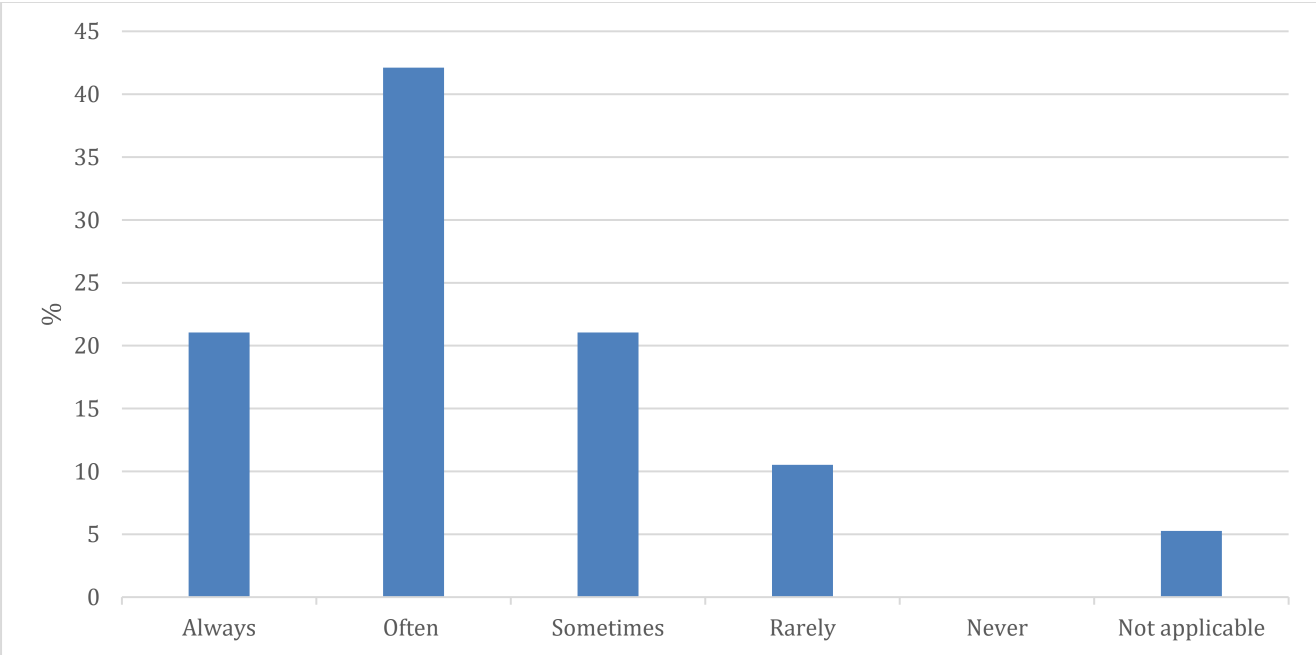
To what degree are the national and technical standards of BIM implemented in your organisation?



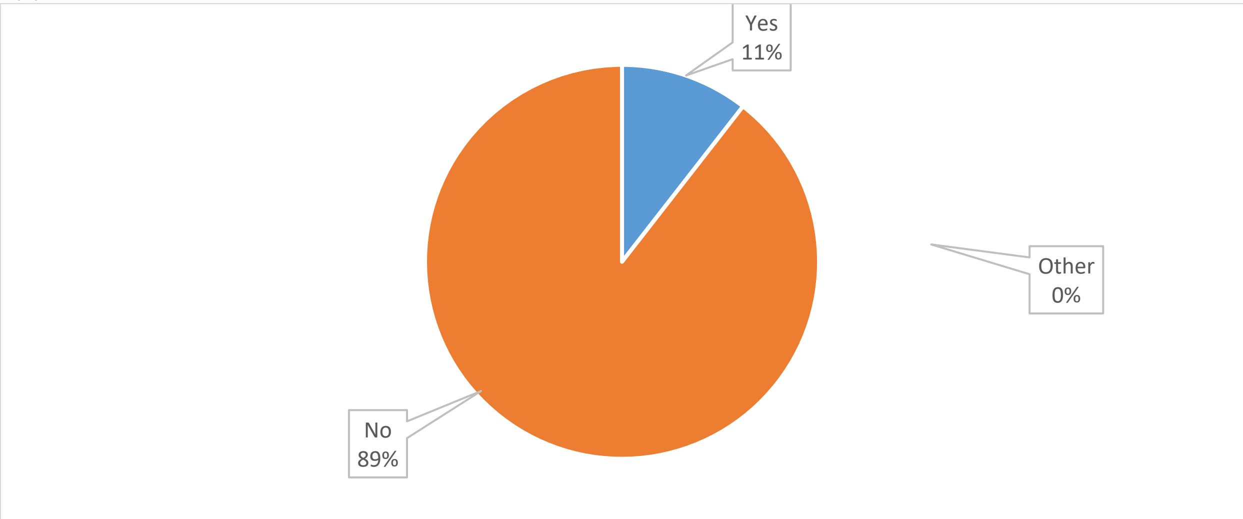
In your experience, how knowledgeable are contractors about national BIM requirements and standards during the tendering stage?



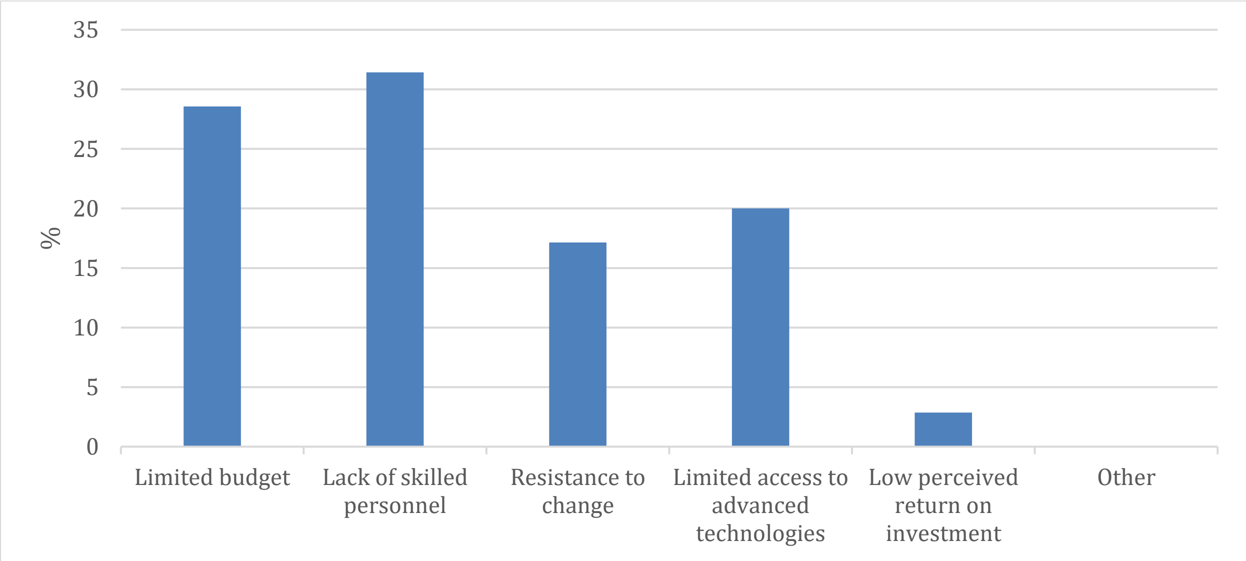
How often do contractors encounter issues meeting the specified Levels of Information (LOI) and Levels of Detail (LOD) required by ASHGHAL at all stages?



Have you faced any legal issues with a contractor specifically related to BIM standards and their application?

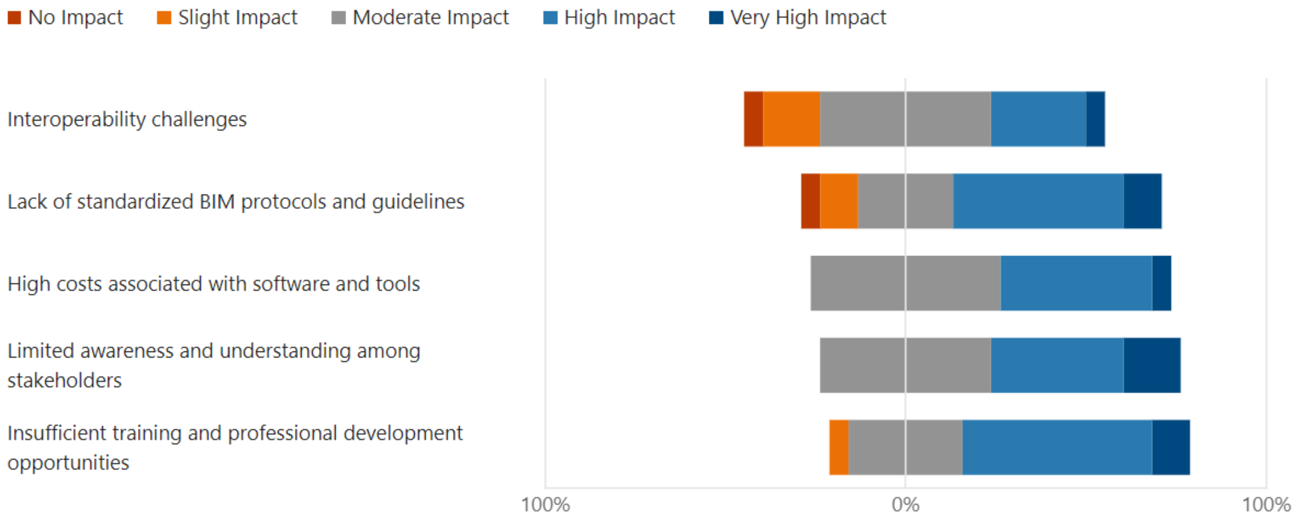


What specific challenges do you think small to medium sized enterprises (SMEs) face in BIM implementation compared to larger enterprises?

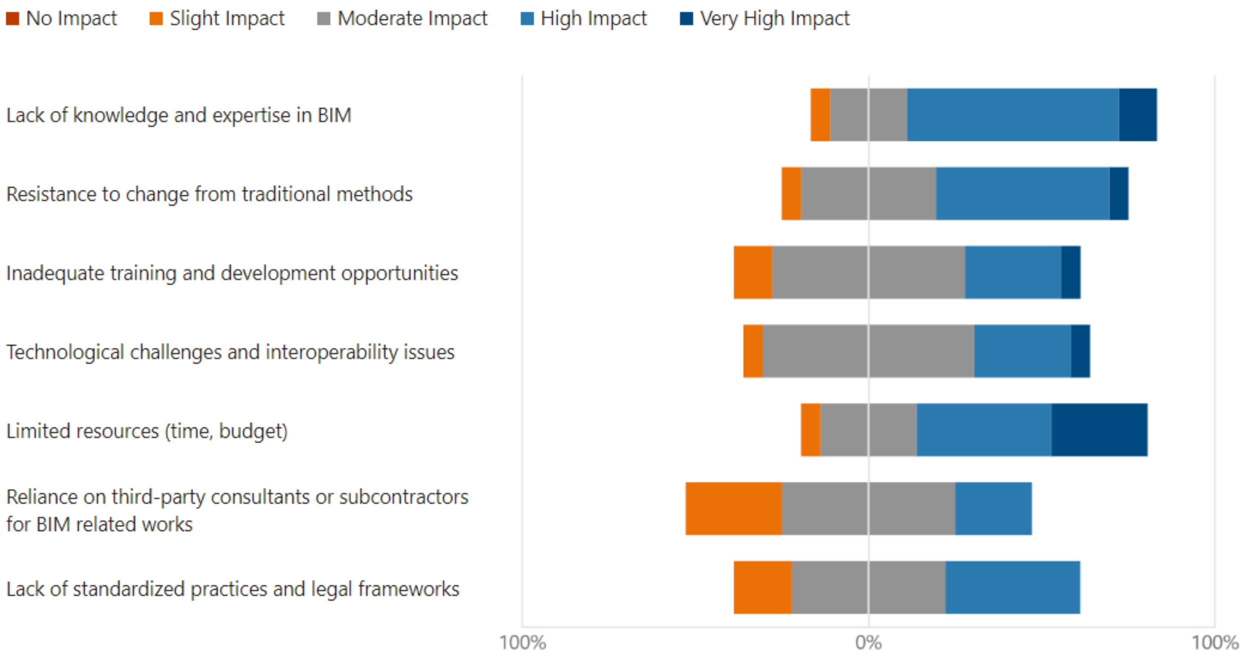


Final Section

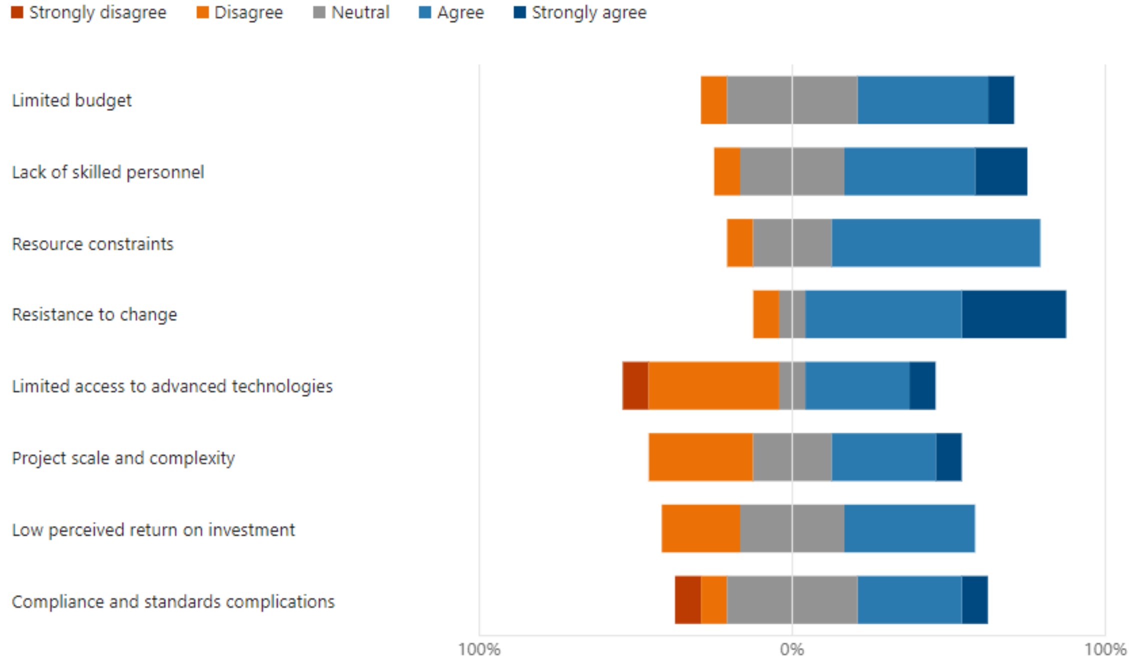
Scale of 1-5 on the impact of the following issues in BIM implementation:



On a scale of 1 to 5, how much is the impact of the following factors has on contractors' problems in adopting BIM?



To what extent do you agree that the following challenges impact SMEs in BIM implementation compared to larger companies?



3.3 Practical Example Findings

The one-way exchange of Revit → IFC → ArchiCAD has shown an enabling degree of flexibility and collaboration across the different software environments, with only minor geometric linking issues as seen in Figure 2.

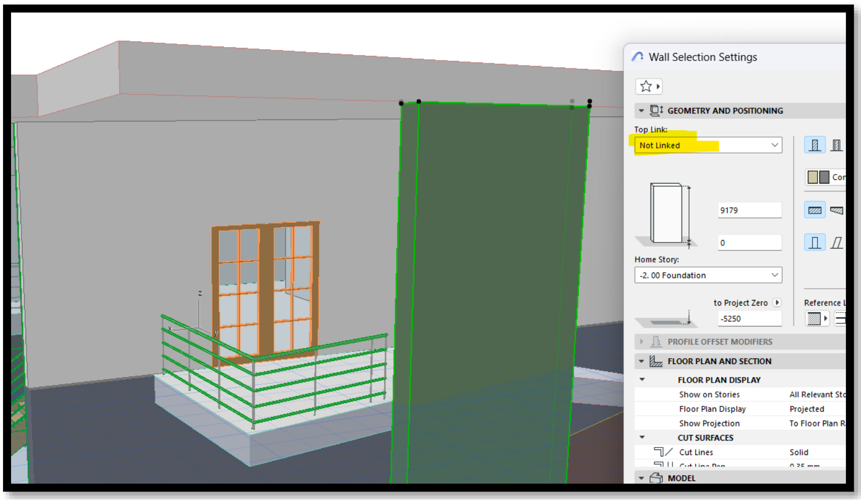


Fig. 2. Missing Link

However, these exchanges are anticipated to be bi-directional. And despite this, the process is shown to be prone to significant challenges, including data loss in Figure 3, mislabelling of elements, and incorrect readings of some of the elements in Figure 4.

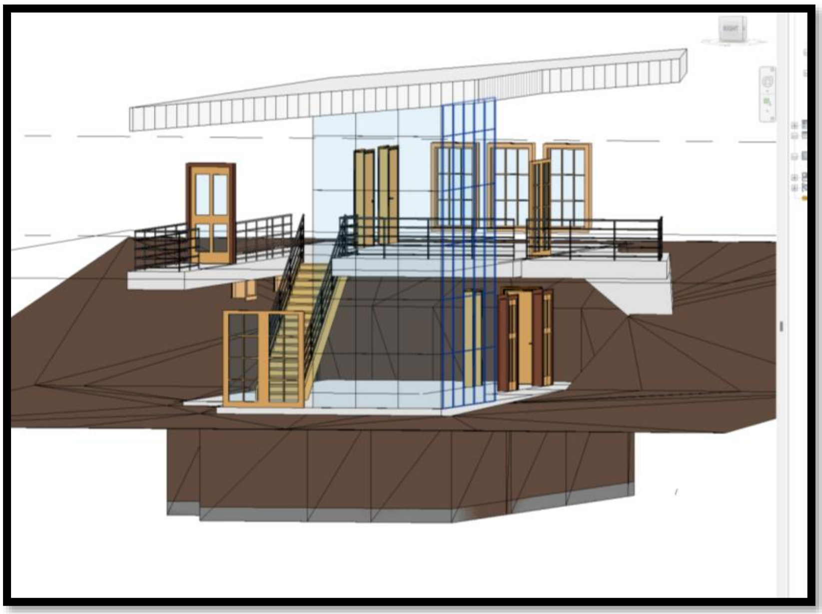


Fig.3. Missing Walls

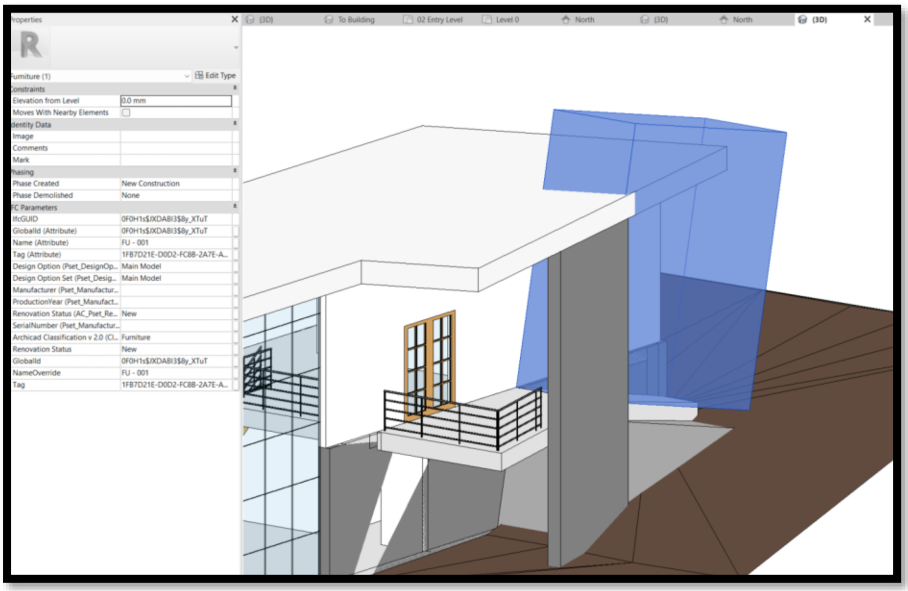


Fig.4. ArchiCAD-IFC Exchange Error

A summary of the errors is shown below:

Process	Errors
(1) Revit – IFC - ArchiCAD	Disconnected elements (Geometry error)
(2) Revit – IFC - Revit	Missing elements
	Missing properties of elements
(3) ArchiCAD – IFC - Revit	Missing Elements
	Incorrect reading of sloped elements
	Additional element is presented

The software versions used for the example are as follows:

Software	Version
Revit	2021
ArchiCAD	27

The integration of BIM in SMEs within the context of public projects presents unique challenges and opportunities. This discussion section will compare the findings from the primary research conducted in Qatar with insights from the literature review, highlighting the most prominent issues identified.

3.4 Technological and Interoperability Challenges

The primary research reveals significant technological and interoperability challenges faced by SMEs in Qatar. The frequent use of tools like IFC and DWG indicates an effort towards standardization. However, frequent data transfers between different BIM software often led to interoperability issues, causing data loss and inaccuracies. This is consistent with the literature, which also highlights interoperability as a critical challenge. For instance, transferring structural models between BIM systems like ArchiCAD, Revit, and ETABS often results in disconnected elements and inconsistencies [11]. The practical example conducted in this research further illustrates these challenges. During modelling and export/import tests between Revit and ArchiCAD using IFC, issues such as disconnected elements, missing properties, and incorrect readings of elements were identified.

This alignment between the practical tests and research findings highlights the critical need for improved interoperability standards to ensure accurate data exchange and enhance BIM effectiveness in the industry. Collaborating with industry stakeholders to develop and implement improved interoperability standards and protocols is essential to ensure seamless data exchange and enhance the efficiency of BIM processes.

3.5 Training and Skills Development

Training and skills development are critical issues identified in both the primary research and the literature. The survey results indicate that while BIM skills among colleagues are generally rated as good or excellent, there is a significant gap in pre-existing knowledge and training resources. The results of the Likert scale also show that the "lack of knowledge and expertise in BIM" has the highest impact on BIM adoption among contractors. The high costs of training programs and resistance to learning new tools further intensify this issue scoring 37% and 22% respectively. This is supported by the literature, which highlights the variability in digital literacy and competencies among the workforce as a barrier to effective BIM implementation [22].

Interviewee (6) highlighted that contractors often lack the required level of BIM expertise to ensure smooth workflow integration with consultant/client entities, reinforcing the preference for developing internal BIM capabilities. The survey results also suggest that issues with contractors' understanding and implementation of BIM are common, with 63% of respondents frequently encountering such problems. Consequently, a substantial majority (79%) perceive that in-house BIM teams for contractors are more efficient than hiring third-party consultants or subcontractors.

Interviewee (2) suggested that developing an in-house BIM team can lead to better integration, quicker communication, and deeper project understanding. This can be achieved incrementally by gradually hiring BIM experts or providing training for existing staff through third-party entities. The alignment of these findings underscores the need for targeted training programs and financial support to bridge the skills gap and ensure effective BIM adoption.

Therefore, the findings emphasize the need for enhanced training programs to address the skills gap in BIM implementation. Targeted training programs should address specific skill gaps and ensure all team members are proficient with BIM tools and processes. Financial support for training is also recommended to alleviate the high costs associated with these programs, as the literature further highlights the lack of attention to essential software skills and the financial burden of training as significant challenges [18].

3.6 Organisational and Cultural Factors

Organisational culture and resistance to change are prominent barriers to BIM implementation highlighted in both the primary research and the literature. The Likert chart identifies resistance to change from traditional workflows as a significant challenge. This resistance is deeply rooted in organisational culture, where established processes and a lack of change management strategies hinder the transition to BIM. The literature validates this, noting that dominant logic and traditional ways of working in the construction industry create friction and hinder BIM adoption [8]. In addition to that, interviewee (4) agrees by stating the resistance to apply BIM processes in the roads sector, which remains dominated by traditional techniques. Both sources advocate for change management frameworks and top management support to facilitate the transition and embed BIM into organisational culture.

3.7 Financial Constraints and Incremental Adoption

Financial constraints are a recurring theme in both the primary research and the literature. The Likert scale highlights the high initial costs of BIM software, hardware upgrades, and training as major deterrents for implementation, in addition to limited time and budget for contractors, with the average of respondents believing that it has a high impact. This financial burden is often perceived as outweighing the benefits of BIM, leading to slower adoption rates. The literature reiterates this issue, emphasizing that the substantial initial investment costs associated with BIM implementation, including software, hardware, and training, are significant barriers for SMEs [48]. Both sources suggest that targeted financial support and incentives are essential to progressively ease these costs and encourage wider adoption of BIM within SMEs.

Incremental adoption and strategic planning emerge as viable strategies for SMEs to overcome these financial constraints. Interviewees suggest that SMEs should start with low-level BIM adoption in privately funded projects and gradually scale up to meet public project requirements. This approach allows SMEs to build competence and confidence in BIM without overwhelming their resources. The literature supports this incremental approach, highlighting the importance of strategic capacity building and continuous improvement in sustainability practices [49]. Forming strategic partnerships with subcontractors and consultants who are technologically adept can help bridge the knowledge gaps and improve technological readiness within the organisation. However, the Likert scale results indicate that many respondents believe that "limited awareness and understanding among stakeholders" is a major barrier to successful BIM implementation. Therefore, by strategically locating skilled partners, organisations can address this issue more effectively.

3.8 Standardization and Legal Issues

The implementation of national and technical standards related to BIM are highlighted in both the primary research and the literature. The survey indicates partial implementation of BIM standards, with contractors often struggling to meet specified Levels of Information (LOI) and Levels of Detail (LOD). Aside from substantial project delays, legal issues arise due to unclear responsibilities and accountability among stakeholders. Similarly, the literature points out the lack of unified standards and clear policy directives as hindrances to effective BIM adoption [29]. In addition to highlighting the importance of clear contractual provisions to determine ownership and responsibility for BIM models [27]. Both sources stress the importance of comprehensive BEPs and clear contract terms to mitigate legal risks and ensure consistency in BIM implementation.

4.0 Conclusion

The implementation of BIM presents a range of challenges that vary significantly between general BIM implementation issues, specific challenges faced by SMEs, and those common to both.

BIM Implementation Challenges:

1. Technological and Interoperability Issues: General BIM implementation is often hindered by technological constraints and interoperability issues among various software tools. The complexity of ensuring seamless data exchange between different BIM software can lead to data loss and inaccuracies, as highlighted by both primary research and existing literature.
2. Training and Skills Development: A major challenge for BIM adoption is the lack of comprehensive training programs. High costs and resistance to learning new tools further exacerbate this issue, resulting in a skills gap that hampers effective BIM implementation.
3. Organisational and Cultural Adaptation: Resistance to change within organisations and the deeply entrenched traditional workflows present significant barriers. Organisational culture often resists the shift required for BIM integration, leading to inefficiencies and a slow adoption rate.

SME BIM Adoption Challenges:

1. Financial Constraints: SMEs face substantial financial barriers, including the high initial costs of BIM software, hardware upgrades, and training. These financial burdens can outweigh perceived benefits, making it difficult for SMEs to justify the investment in BIM.
2. Limited Technical Expertise: SMEs often lack the necessary technical expertise and resources to effectively implement BIM. The challenge of creating bespoke information workflows and understanding complex terminologies further complicates BIM adoption for SMEs.
3. Policy and Standardization Issues: Adhering to national and technical standards such as ISO 19650 is particularly challenging for SMEs due to their limited resources and digital maturity. The absence of supportive policies that cater to the unique needs of SMEs further impedes their ability to adopt BIM.

Common Challenges:

1. Interoperability: Both SMEs and larger enterprises struggle with interoperability issues, highlighting a universal need for better standardization and protocols to ensure seamless data exchange and maintain data integrity.
2. Training and Development: Across the board, there is a significant need for targeted training programs and financial support to bridge the skills gap and ensure all team members are proficient in using BIM tools and processes.
3. Change Management: Implementing an effective change management structure is crucial for both SMEs and larger firms. This involves top management support and strategies to manage the human aspects of transitioning to BIM, which is essential for overcoming resistance and ensuring a smoother implementation process.

In conclusion, while BIM presents numerous benefits for the construction industry, its implementation still faces multiple challenges that need to be addressed through strategic planning, financial support, and robust training programs. SMEs, in particular, require tailored policies and incentives to overcome their unique challenges and fully leverage the potential of BIM. Improved interoperability standards and a supportive organisational culture are essential for successful BIM adoption across the industry.

Acknowledgement
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